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OBSERVATION OF $\phi^{o}\phi^{o}$ PRODUCTION IN 400 GeV/c PROTON-PROTON INTERACTIONS

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Abstract

Inclusive $\phi\phi$ production has been observed in p-nucleon interactions at 400 GeV/c. The number of events is larger than expected for uncorrelated ϕ pairs. There is some excess of correlated events at a mass $M_{\phi\phi}$ near 2110 MeV/c^2.

This note describes preliminary test data on inclusive $\phi\phi$ production in 400 GeV/c p-nucleon interactions. The data was taken during a 60 hour test run used to debug the trigger processor to be used in E623. It consists of 20,000 triggers which corresponds to 1 hour of normal data taking. The main motivation for E623 is to look for η_c production through a possible $\phi\phi$ decay mode. In addition, the $\phi\phi$ final state selects C=+1 mesons and an OZI allowed decay should select mesons containing hidden strangeness or having exotic structure. In particular, gluon bound states, glueballs, can decay into $\phi\phi$[1].

The only previous data on $\phi\phi$ inclusive production in pp interactions at high energies contained 3 $\phi\phi$ candidates[2]. In π^-p interactions low mass $\phi\phi$ were studied at 100 GeV/c yielding 52 candidates, and high mass $\phi\phi$ were studied at 175 GeV/c yielding 279 candidates[3]. In terms of a quality factor defined to be $\phi\phi$ candidates per trigger the present data consists of 32 candidates or 1/700. The π^-p data has a quality factor of 1/4000 and 1/12000 at 100 and 175 GeV/c respectively. This comparison shows the advantage of using a fairly sophisticated trigger processor. In a 500 hour data run, one may obtain 16,000 $\phi\phi$ candidates using the trigger algorithm which was used in the test run. In fact, improvements have been implemented which will improve the signal/noise quality factor by at least a factor of two.

The data were obtained during a test run of experiment E623 at the M6W beam of the Meson Laboratory. A schematic plan view of the apparatus is shown in Figure 1. The main elements of the trigger are 3 PWC hodoscopes H_1, H_2, and H_3 each consisting of 32 elements of width 1.6cm, 3.2cm, and 6.4cm respectively and a 30 element multicell cherenkov counter C_2 segmented roughly into equal cell spacing in pseudorapidity.

Detector locations were chosen to optimize the detection efficiency for centrally produced η_c. The choice of N_2 for the C_2 gas was also dictated by this requirement. A Monte Carlo program was written to produce the η_c using a phenomenological model[4], let them decay, and track the charged kaons through the apparatus. The efficiency to pass through H_1, H_2, and H_3 and to be above pion threshold but below kaon threshold in C_2 ($6<p_K<22$ GeV/c) was found to be $\varepsilon_K=0.71$. Thus $\varepsilon_\phi=0.42$ and $\varepsilon_{\phi\phi}=0.15$. The detection efficiency peaks at $x_{\eta_c}\sim0.1$ and has a FWHM in $x_{\eta_c}\sim0.15$. The efficiency is insensitive to $p_{\perp\eta_c}$ for $p_{\perp\eta_c}<2.0$ GeV/c.

The Monte Carlo program also generated lists of allowed coincidences for the hodoscopes, $H_1^i \cdot H_2^j \cdot H_3^k \cdot \bar{C}_2^l$. All listed coincidences were wired in a trigger processor whose details are given elsewhere[5]. The hodoscope multiplicity in H_3 was required to be $4\leq N_{H_3}\leq 10$. In addition the number of valid coincidence candidates (called $K^{\pm}$) was required to be $N_{K^+} \geq 2 \cdot N_{K^-} \geq 2$. The processor then used the hodoscope addresses for valid coincidences to roughly calculate the K^+K^- mass and transverse momentum in the bend plane. The mass was required to be small for both the left most and right most K^+K^- combinations. The final trigger rate was ~ 10 μb. The option to bias the data toward large $\phi\phi$ masses by requiring large ϕ transverse momentum was not imposed during the test run, although it will certainly be used during the main data taking.

During interruptions in data taking calibration runs using light flashers were taken to find the photoelectron equivalents of both C_1 and C_2. The data was then passed through pattern recognition and track fitting programs[6]. The resulting tracks were propagated to C_2 and kaon candidates were required to have no light in the appropriate mirror. The typical spectrometer ($x>0.0$) multiplicity was 10. Of all triggers about 10% have at least 2 K^+ and at least 2 K^- which were reconstructed successfully.

The K^+K^- mass spectrum for these events is shown in Figure 2. In this figure, and in subsequent figures, the smooth curves represent combinatorial background. These curves are generated by combining K^+ from one event with K^- from 10 other distinct events. The normalization is set by dividing the resulting histogram by 10. Clearly the background under the ϕ is substantial and comparable to that found in reference 2. The background is less severe in the lower energy $\pi^{-}p$ data given in reference 3. However, one should gain a factor ~4 in η_c production cross section in going from 100 to 400 GeV/c[4]. The only features above background are the ϕ meson and a possible low mass enhancement due to known mesons (see also ref. 2).

Using the observed ϕ width, one infers dM_{ϕ} from which the 4K mass resolution may be calculated. Typical values are $dM_{4K}=\pm 10$ MeV/c^2 at $M_{4K}=2.1$ GeV/c^2 and $dM_{4K}=\pm 25$ MeV/c^2 at $M_{4K}=3.0$ GeV/c^2. The $K^+K^-K^+K^-$ mass spectrum is shown in Figure 3. Within the available statistics no feature above the combinatorial background is apparent.

A low mass $(K^+K^-)_1$ vs $(K^+K^-)_2$ scattergram is shown in Table I. The 32 candidate events in the $\phi\phi$ overlap region can be attributed to the following categories; 22.9 $K^+K^-K^+K^-$ events, 0.3 ϕK^+K^- events, and 8.8 $\phi\phi$ events. Assuming uncorrelated production of ϕ mesons, one expects only 0.7 $\phi\phi$ excess events. The mass distribution of the 32 $\phi\phi$ candidates is shown in Figure 4a. The background of 23 combinatorial events is shown as a smooth curve. As is true for the data of Ref. 3, this curve peaks at 2080 MeV/c^2. It is amusing to note that the residual 9 events shown in

Fig. 4b are largely contained in a single 20 MeV/c^2 bin at 2110 MeV/c^2 as is also true for the data of Ref. 3. The data given here has 6 events on a background of 2 while that of Ref. 3 has 14 events on a background of 4 events. For 100 GeV/c $\pi^- p$ interactions it is estimated in Ref. 3 that $\sigma_x B(x \to \phi\phi)$ is 0.34 μb for M_x=2110 MeV/c^2. For this data one estimates 0.7 μb. However, given the model dependence of the efficiency this estimate is undoubtedly uncertain by at least a factor of 2.

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TABLE I

$M_{(K^+K^-)_1}$ vs $M_{(K^+K^-)_2}$ at low K^+K^- masses

$M_{(K^+K^-)_2}$ (GeV/c^2): 1.069 (top) to 0.989 (bottom)

1.069	31	21	25	24
	25	28	16	19
$M_{(K^+K^-)_2}$ (GeV/c^2)	21	32	17	21
0.989	18	29	24	24
	0.989			1.069

$M_{(K^+K^-)_1}$ (GeV/c^2)

References

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4. M. Bourquin and G.M. Gaillard, Nucl. Phys. B114 (1976) 334.

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6. H. Wind, Nuc. Inst. Meth., 115 (1974) 431.

Figure Captions

1. Schematic plan view of the apparatus showing the main detector elements. The main elements used in the trigger are PWC hodoscopes H_1, H_2 and H_3 and a multicell cherenkov counter C_2.

2. K^+K^- mass spectrum for $pp \to K^+K^-K^+K^-X$ events. The smooth curve is an absolutely normalized combinatorial background generated as described in the text.

3. $K^+K^-K^+K^-$ mass spectrum for $pp \to K^+K^-K^+K^-X$ events. The smooth curve represents combinatorial background.

4. $\phi\phi$ mass spectrum

   a) all 32 candidate events with combinatorial background normalized to 23 events

   b) plot a) but with the combinatorial background subtracted.

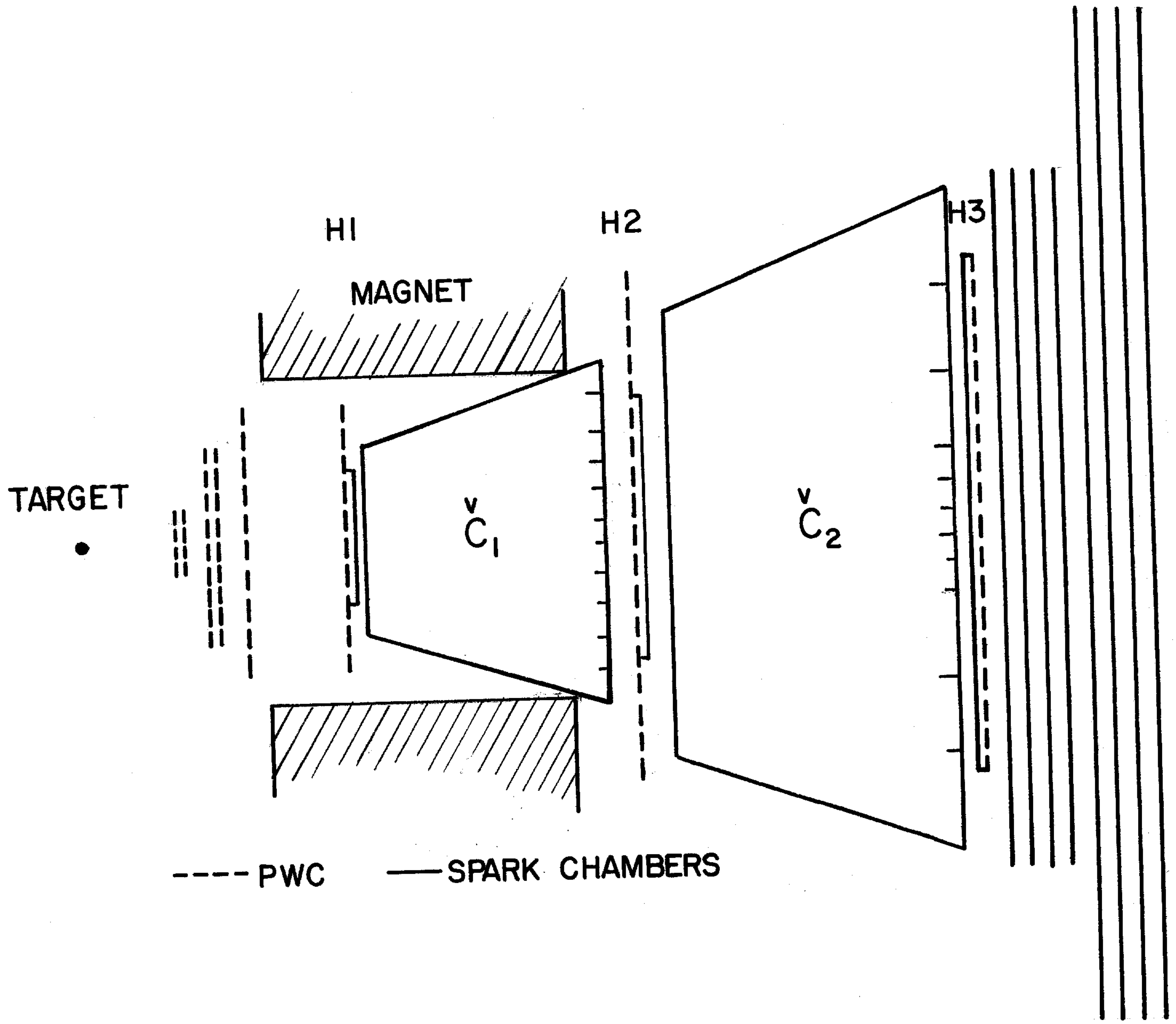

Fig. 1

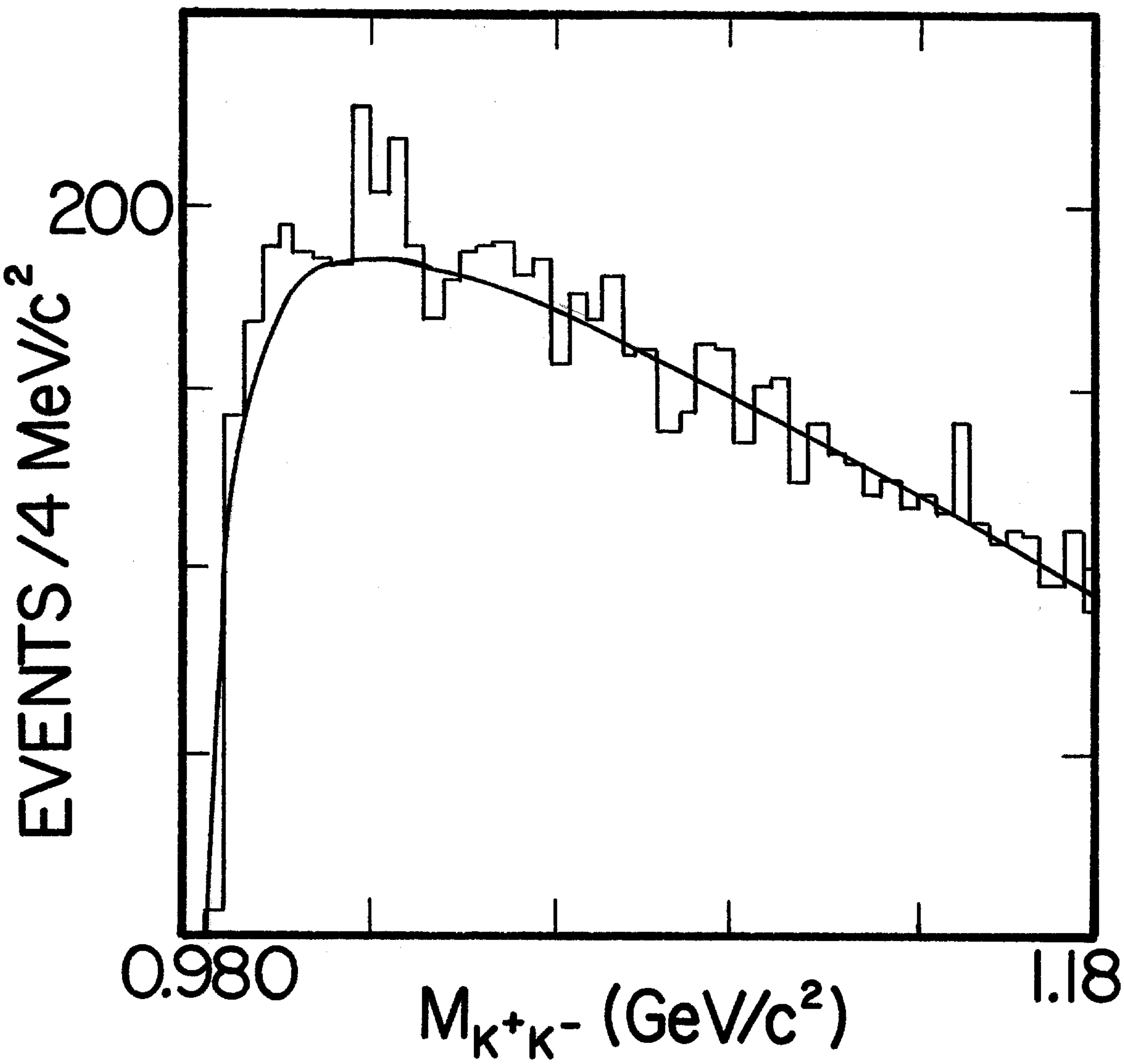

Fig. 2

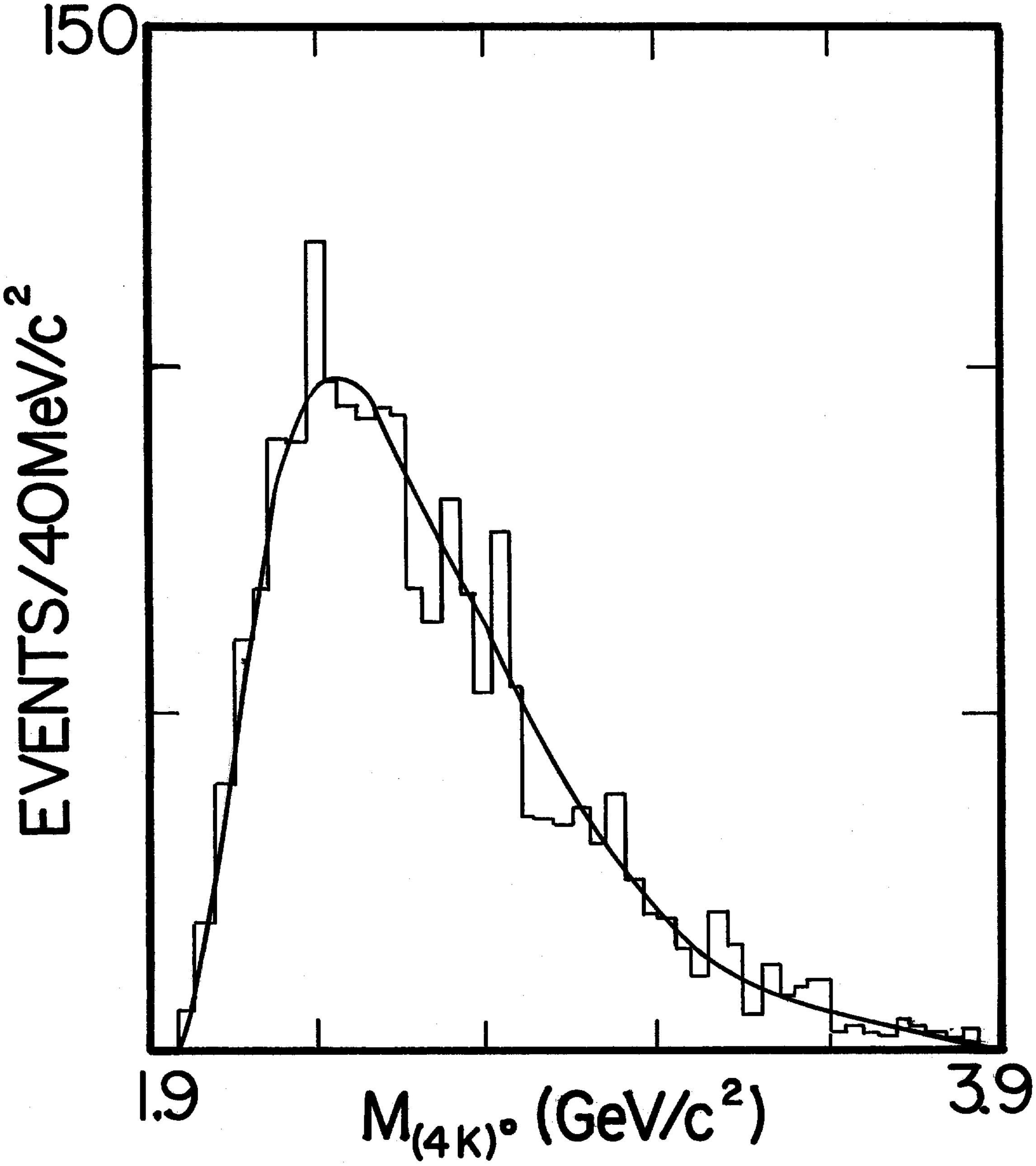

Fig. 3

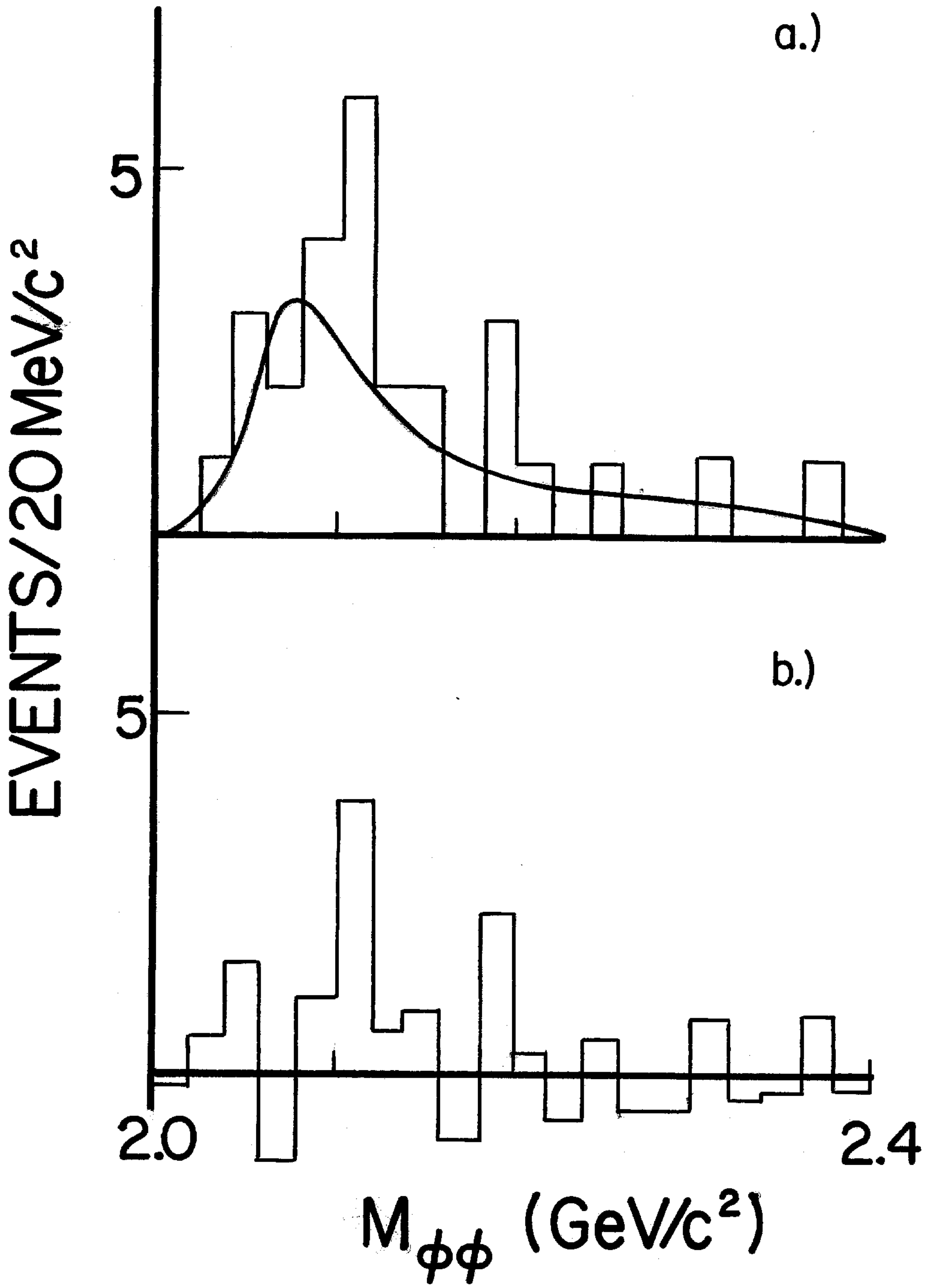

Fig. 4